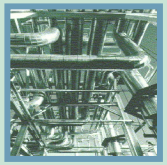
State-of-the-Art District Heating (DH) Systems in Europe



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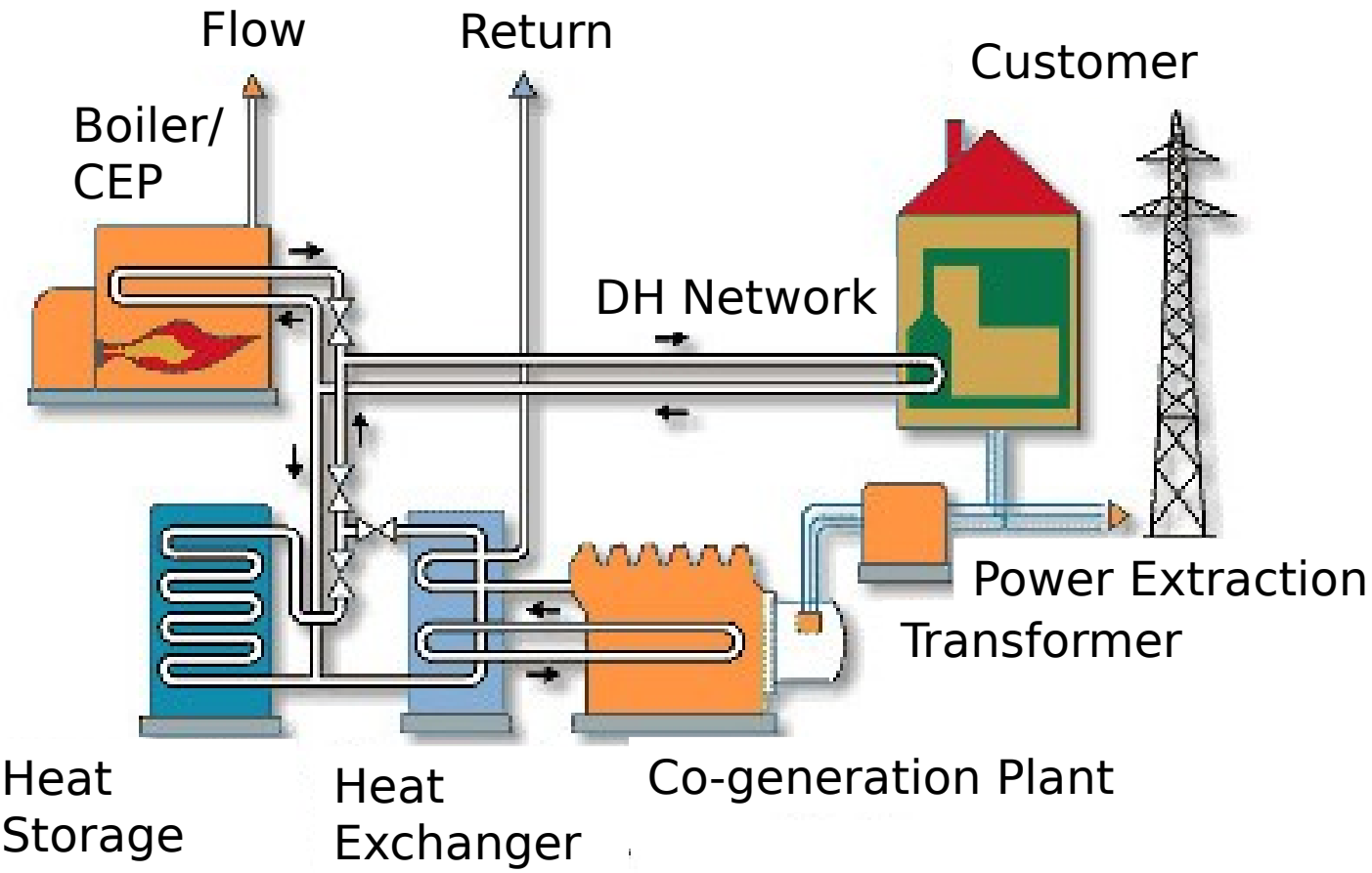
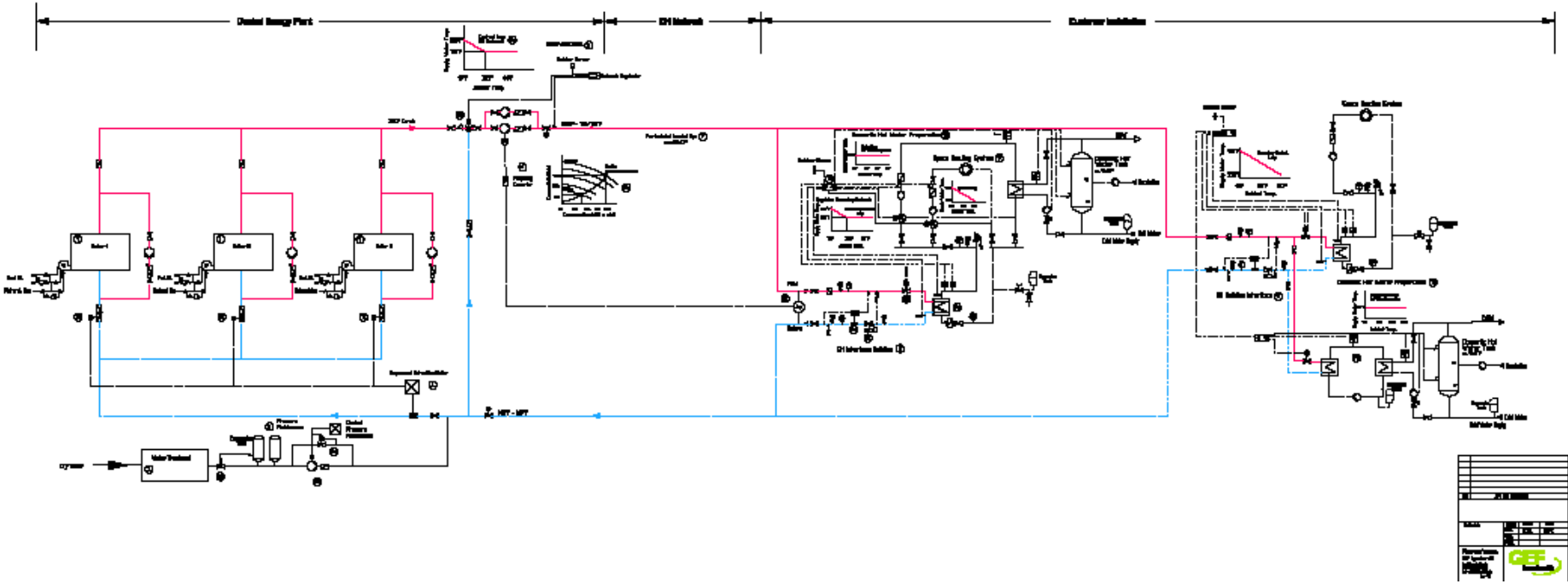
DH-System at a Glance



DH-System at a Glance

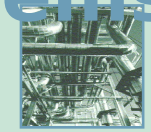
Generation Distribution Substations/Customers



Outline

1. Some Basics on District Heating Systems
   - Generation
   - Piping
   - Substations

2. Examples of Optimization in DH in
   - Proposed Optimization Issues in Hot Water Systems in US Army Installations
   - Conversion of Steam based DH Systems to Hot Water Systems



Generation

Type of Generation

- Central Energy Plant (CEP) or Major Energy Source (MES)
- not restricted by size or fuel
- can be classified into waste heat and fresh heat generation
- can be classified into secured and unsecured capacities

Type of Plants

- heat only, co-generation (CHP) and tri-generation plants
- depending on the profit relationship between e.g. power and heat
- basic principle for decisions are economic

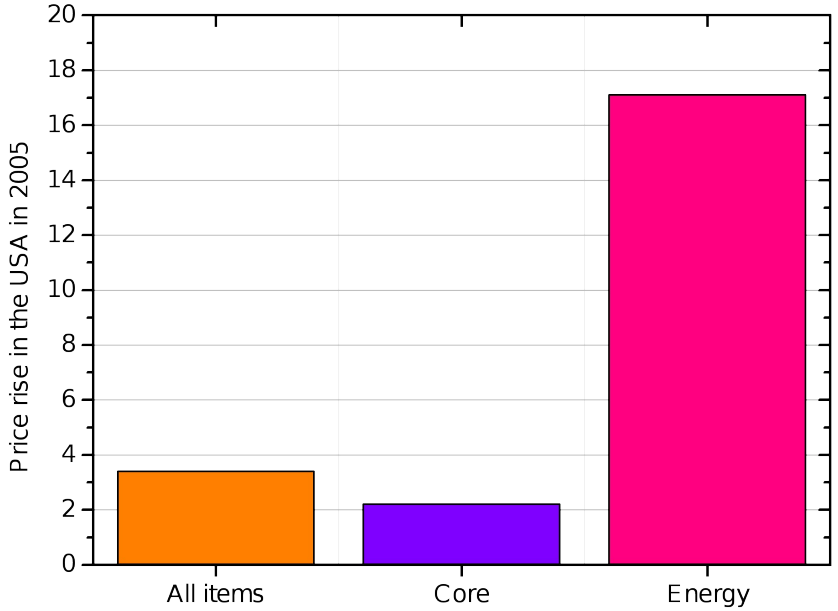
Size of Plants

- Size and number of the CEP/MES depends on both, required capacity and hydraulic situation given by the piping system. For the hydraulic control in most cases heat only plants are used; the same for peak load and as back-up. CHP and tri-generation plants are operated as base load plants.
- Size of a plant, number of sites and number of operators are determined by peak load of the DH system, the contingency of passing out power to the grid and the hydraulic restrictions of the piping system
- stuff/operators are reduced to a minimum. (In DH system with 15,500 trillion BTU annual heat sale, with 3 CHP plants and 6 heat plants, a crew of 2x3 co-workers operates the entire system in a shift (each crew consists of one plant operator, one heat and one power dispatcher)
- heat plants are remote controlled and attended once a day for less than an hour.

Generation

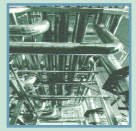
Additional Keywords

- Water Treatment
- Pressure Maintenance
- Sequenced Actuation Boiler
- Remote controlled Heat Plants
- ...

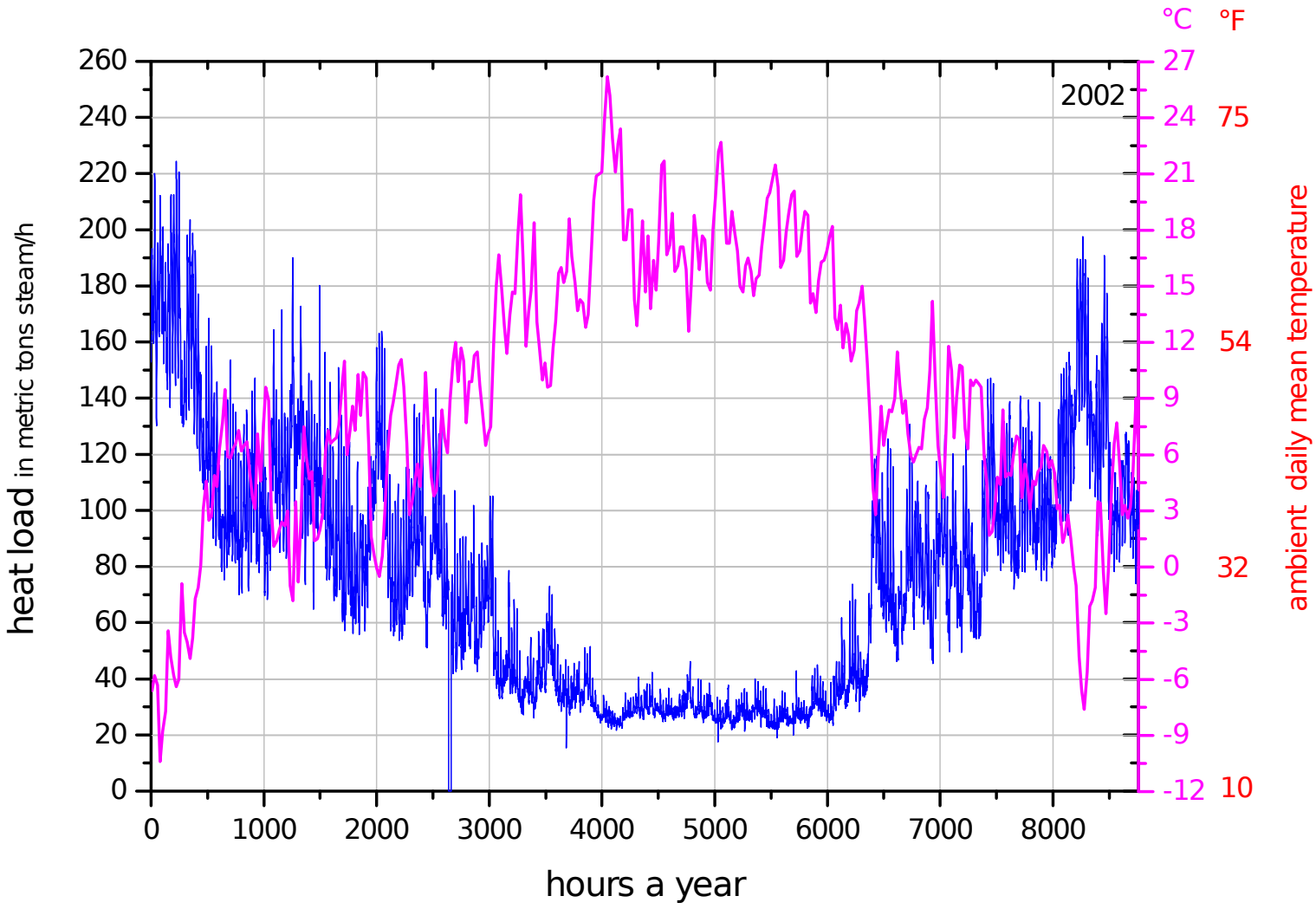


Advantages of CEP/MES compared to single boilers (decentralized supply)

- ease to diversify the fuel (e.g. in an army installation) and ease to switch to another fuel
- security of supply is high since the dependency of one single fuel is minimized
- costs/prizes for heat supply are constant over long periods of time
- personnel expense to maintain a reliable heat supply can be reduced to a number of specialists
- contracting models are applicable
- ...



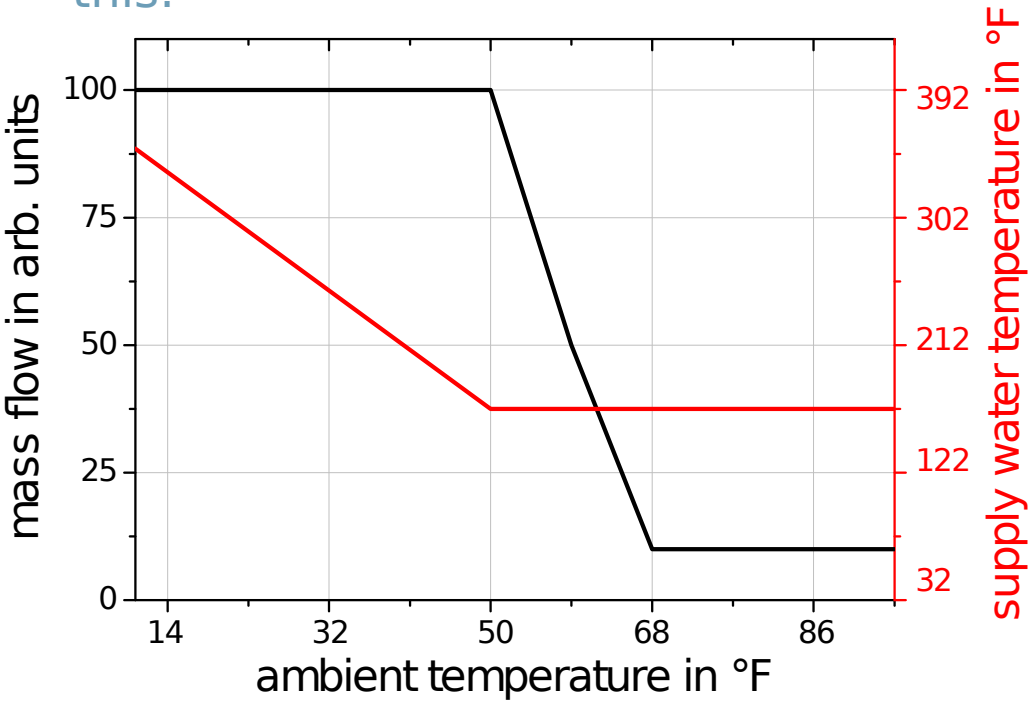
Load Curve of a DH System



Adapting to the Ambient Temperature

Since the demands of space heating and domestic water has to be covered, the peak load case has to be found. Those conditions will be set as the optimum for the pressure head of the pumps.

Then the supply temperature has to be adapted to the ambient temperature while installing a control. A temperature curve can look like this:



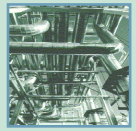
Δp = const.

Main equation: $\dot{Q} = \dot{m} \cdot c \cdot \Delta T$

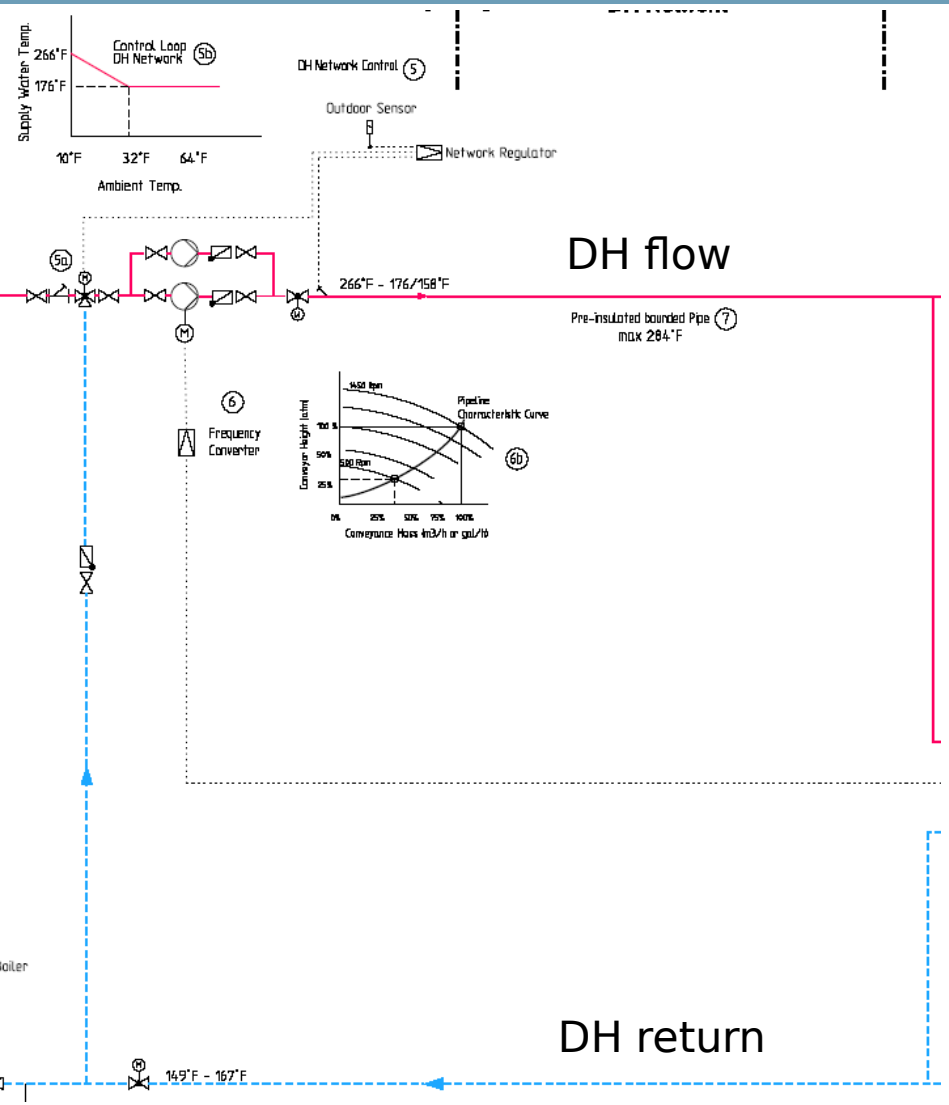
i.e. reducing ΔT affects the mass flow of water pumped through the pipes. However, the pipes diameter is fixed, hence the pressure difference and the mass flow are the most relevant parameters!

Questions to be Checked before reducing

- Allows the design of the space heating systems inside the buildings the reduction of the supply water temperature? What is the use of heat inside the building?
- What are the design-parameters of all the pipes, fitting etc. (temperatures, pressures)?
- How are the heat exchangers inside the buildings designed?
- Is it possible to install a temperature-shift for night-time (11 p.m. to 6 a.m.) and week-ends in order to meet the daily/weekly peaks?
- Is it acceptable to install an ambient and room temp. bound control?
- …



DN Network



Adapting the DH network temp. to the ambient temp. → frequency converter for variable RPM-regulated pumps is required

Sliding flow temps. with a max. at 285°F ensures the usage of pre-insulated bounded pipes (plastic jacket pipes).

Pre-insulated bounded pipes are the most common piping system in Europe.

Pre-Insulated Bounded Pipes

Advantages of these Pipes

- directly buried
- hardly any manholes
- no concrete needed
- fast laying
- leak detection system
- low prices due to batch production
- up to DN 300 (1ft.) no compensation required
- less expensive new connections and replacement
- precasted fittings and elbows
- spott-drilling for connecting new customers under pressure

Limitation

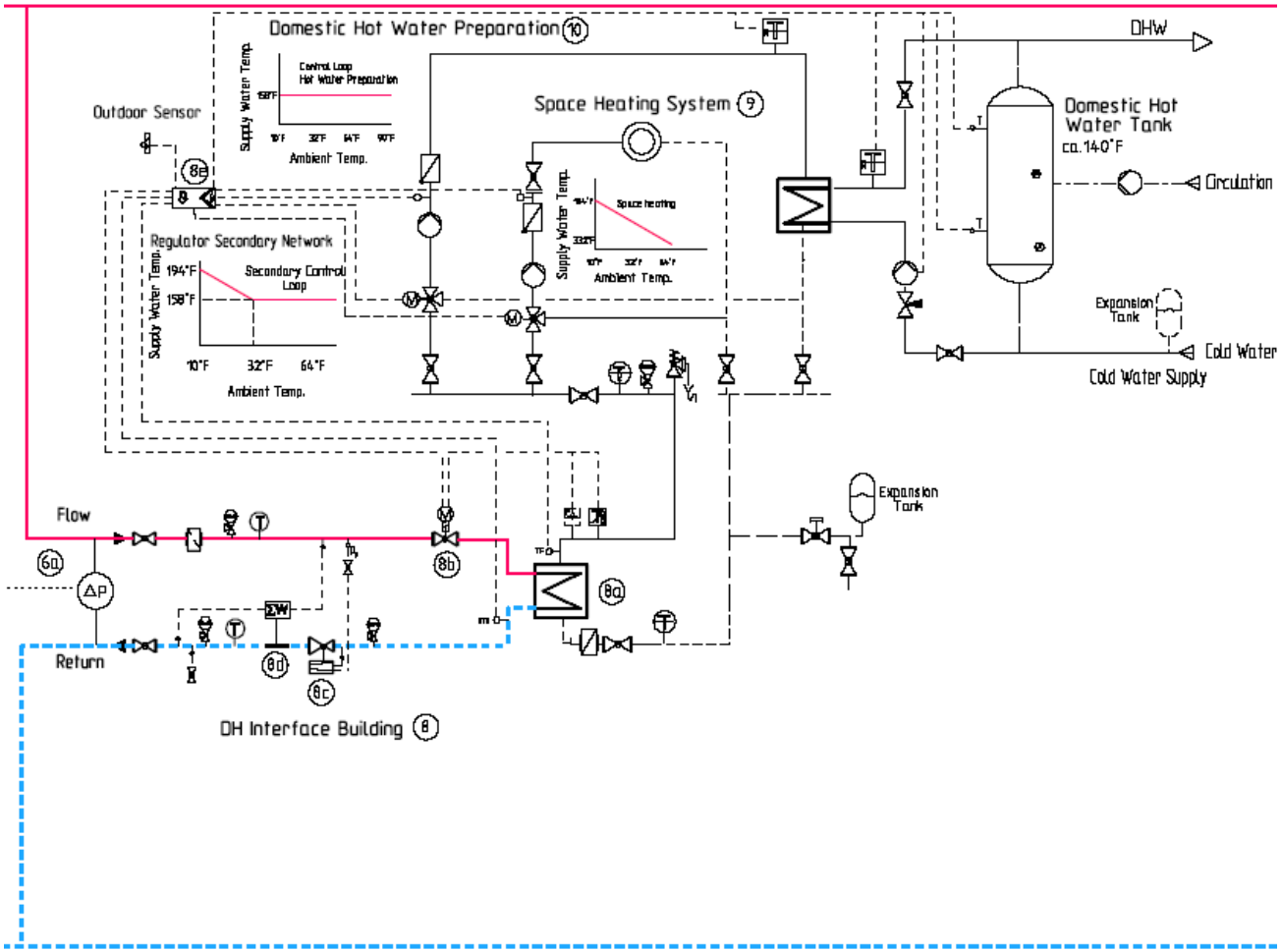
- Max. acceptable temperature is limited to 285°F (expected lifetime of 30 years)
- Reduction of annual average temp. to 195…210°F extends the lifetime twice

Other Pipe Systems

- Steel jacket pipes
- in-situ insulated pipes in dome-shaped ducts
- above ground level pipeline and many more

Substations and Customer Stations

DH flow



DH return

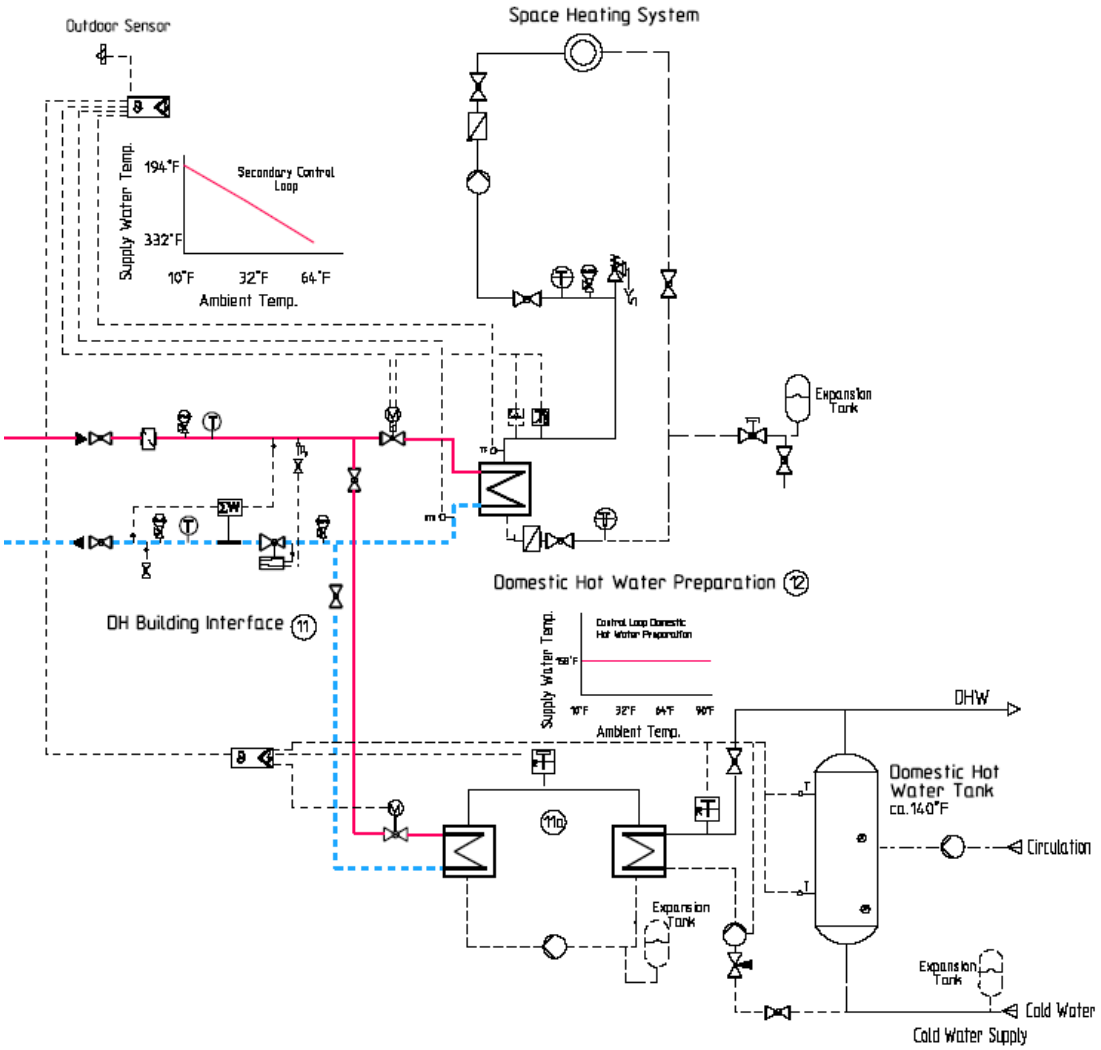
Indirect substation with serial Domestic Hot Water (DHW) preparation in an additional loop.

Lowest flow temp. in the system is at 160°F to ensure hygienic standards (legionnaires' disease).

A heat meter controls the ΔT and the mass flow into the building and calculated the consumed heat.

The differential pressure is maintained between 1.5 and [illegible] psig.

Substations and Customer Stations



Indirect substation with parallel Domestic Hot Water (DHW) preparation with an among loop in-between.

Lowest flow temp. in the DHW system is at 160°F to ensure hygienic standards (legionnaires' disease).
In the space heating system the flow temp. can be reduced to 86°F.

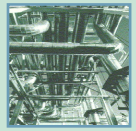
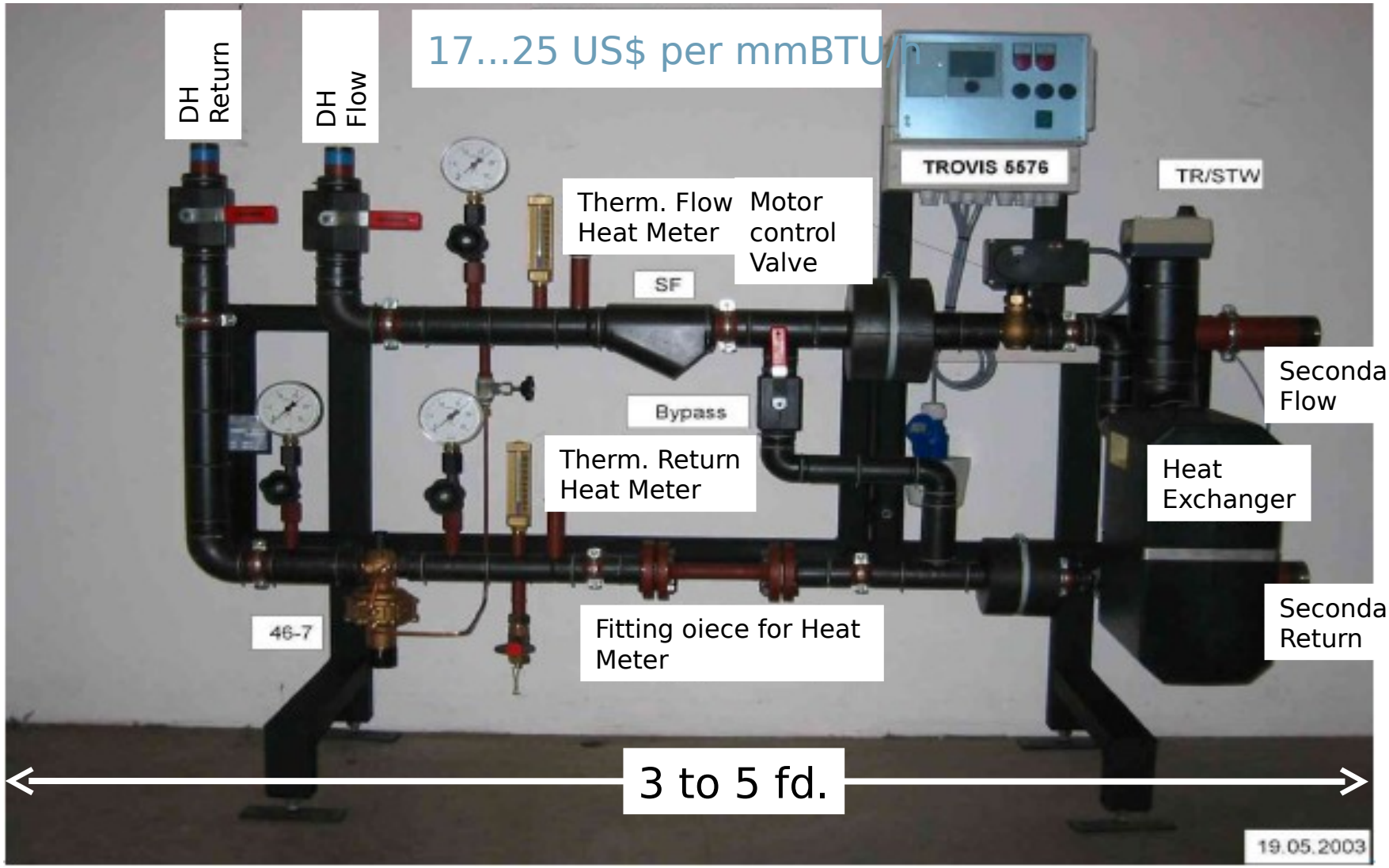


Photo of a modern Compact Station



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On-Site Assessment Ft. Stewart, Georgia

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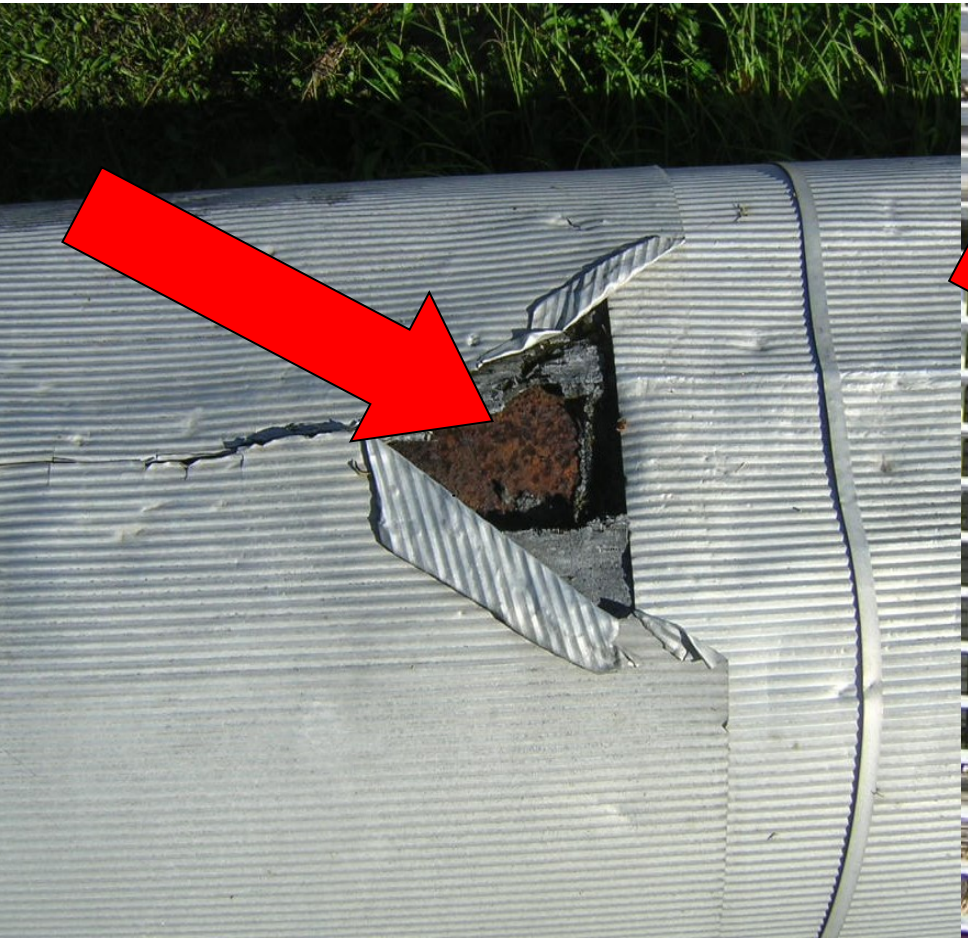
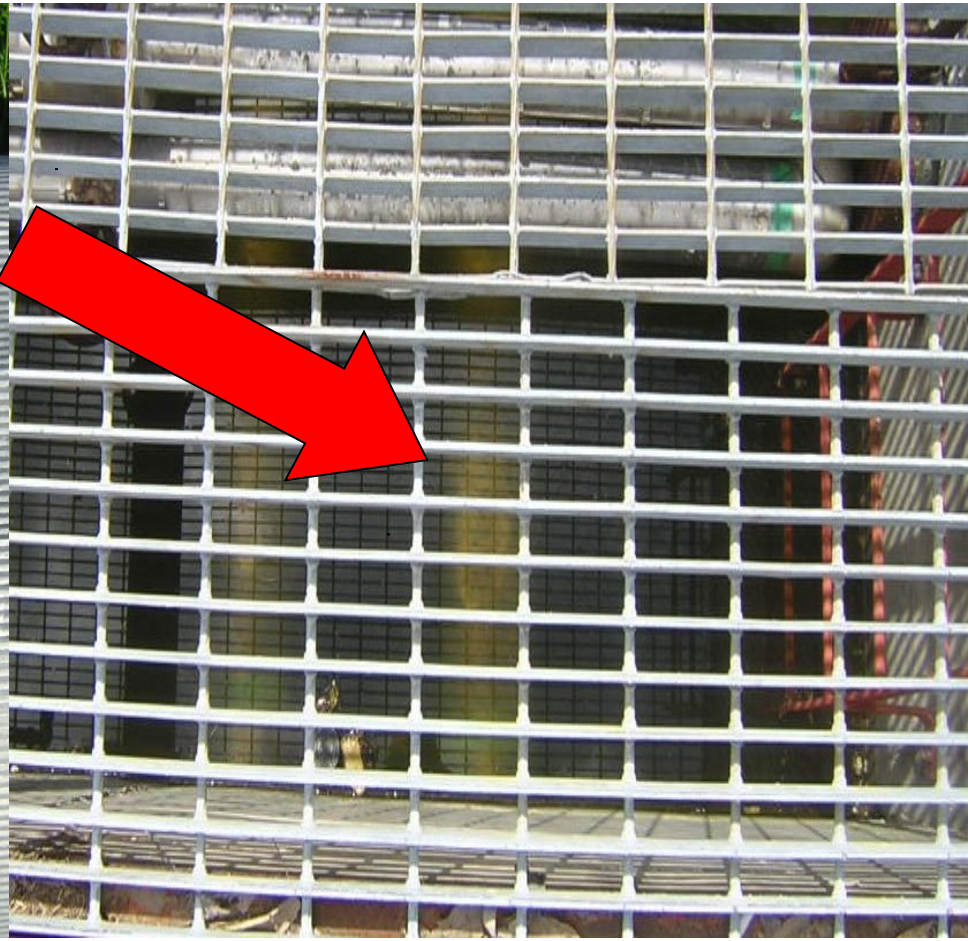
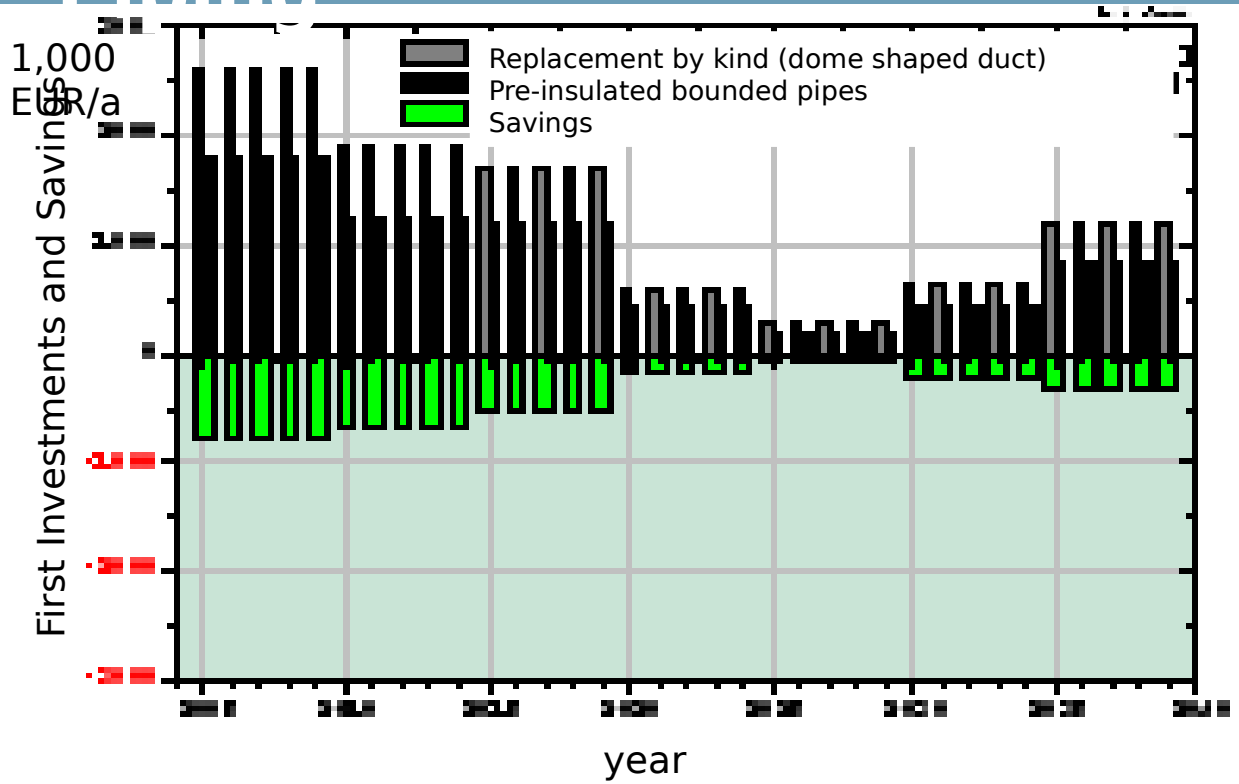




Reducing the Costs for Retrofitting in Piping

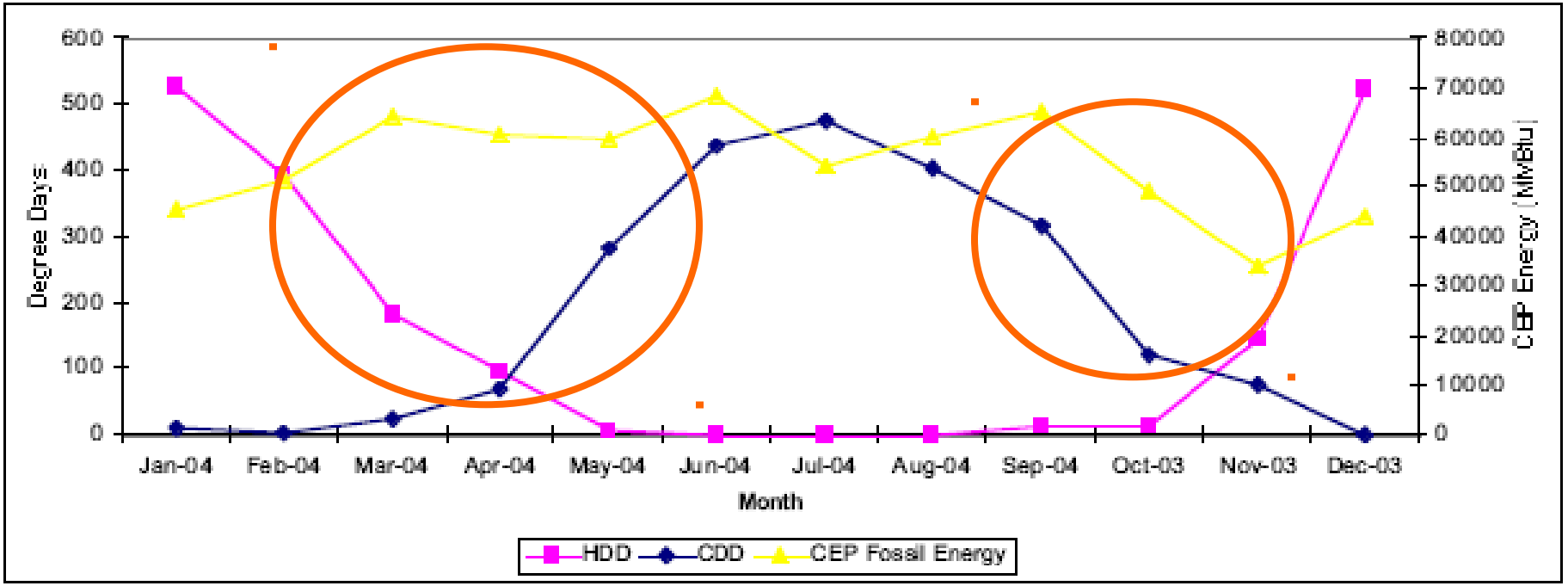


Costs required for piping per ft. installed pipeline (diameter of 4 inches):
pre-insulated bounded pipes (in Europe):
~ 200 $/ft.

Current piping system: ~1,200 $/ft.

Replacement campaign for 14 miles pipelines

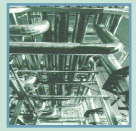
Load Profile of Demand and Generation



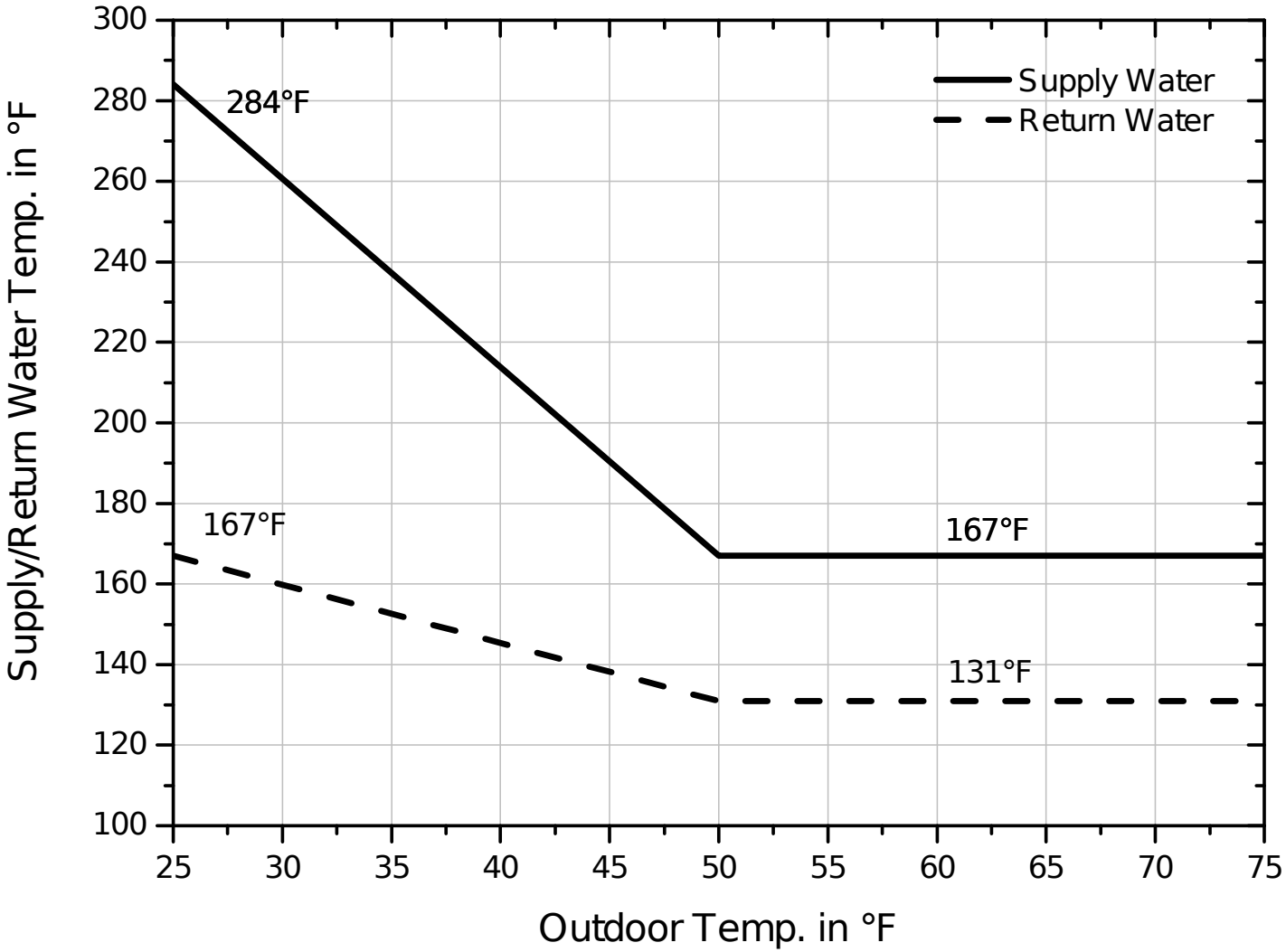
Options for Improvements at Ft. Stewart

Reduce the temperature levels in the district heating system

- Reduction of T_{flow} and T_{return} while stays at its ΔT extend
- Lower flow temperatures offers the opportunity to use pre-insulated bounded pipes which is at least five times cheaper than the currently installed system.
- For critical consumers of the high temperature hot water different alternatives are possible: The hospital can use its own boilers for post-heating; electric dishwashing does not need those high temperatures.
- After reducing the supply water temperatures a sort of economizer can be installed in the flue gas with its high temp (~400°F) and its high moisture content. The energy in the flue gas can be used for a pre-heating of the return water. That results in an additional reduction of fossil fuel



Variabel Operation Temperatures



Reduction of Heat Losses

Reduction of annual mean supply temperature

heat losses FY2004: **150,000 mmBtu/a**

Share of losses in supply water ~ 70%

$Q_{lost, SW, today}$ = 105,000 mmBtu/a

Approach: $Q_{lost} \sim \Delta T$

$\Delta T_{today} = T_{VL} - T_{ambient} = (205 - 70)°F = 135°F$

$\Delta T_{future} = T_{VL} - T_{ambient} = (380 - 70)°F = 310°F$

Thus, the today's heat losses Q_{today} result into

$Q_{loss, SW, future} \approx 105{,}000 \text{ mmBtu/a} \times ({}^{135}/_{310}) \approx$ **45,200 mmBtu/a**

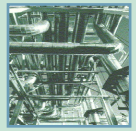
Share of losses in return water ~ 30%

~~$Q_{loss, RW, future} \approx 150{,}000 \times 0.3 \times \text{mmBtu/a} \times ({}^{80}/_{150}) \approx$ **23,900 mmBtu/a**~~

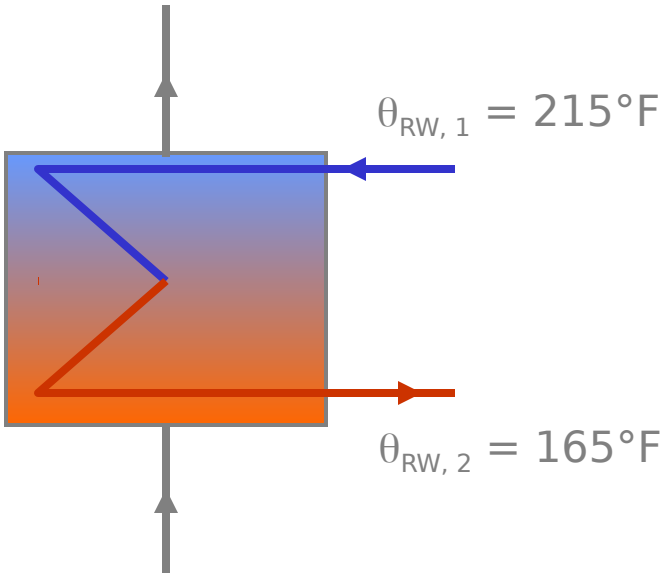
Reduction of heat losses caused by reduction of supply water temperature:

(45,200 + 23,900) mmBtu/h = **69,100 mmBtu/a**

Equals 23% of the total heat production in FY 2004



Efficient using of flue gas energy Q_{FG} maybe as pre-heating of return water



$\dot{V}_{FG}$ = 78 klb/h

$\dot{Q}_{FG}$ = 47 MMBtu/h

Additional heat energy potential:

Q_{FG} = 47 mmBtu/h × 7,000 h/a

≈ 21,500 mmBtu/a

(equals 15% of the total heat production in FY 2004)

Saving in fuel/resources:

55,700 US-$/a

Required investments:

160,000 US-$ once

Outlook

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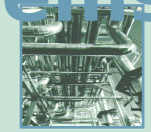
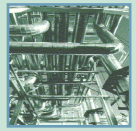
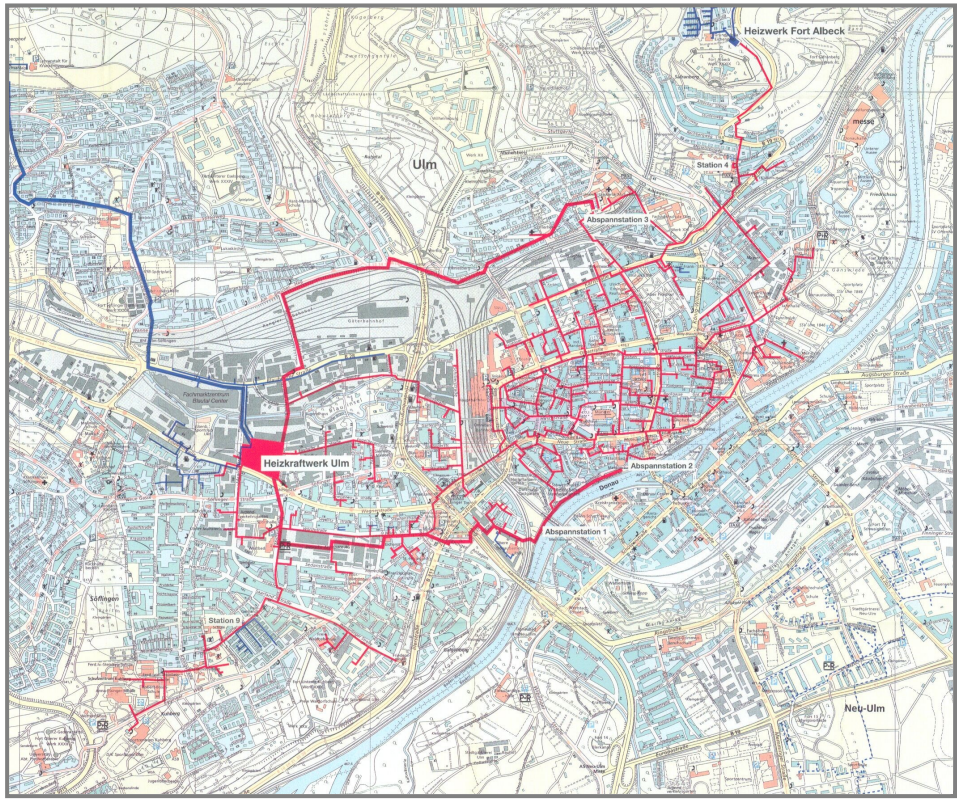


Steam Systems in Europe Economic terms are calling for Conversion

City	Connected Load [Bill. BTU/h]	Conversion	Conversion Period
Hamburg	13	in progress	2002-2010
Kiel	17	in progress	2002-2012
Munich	65	in progress	2003-2012
Salzburg	9	in progress	2005-2009
Ulm	8	detailed study in progress	?
Paris	224	currently under GEF's investigation	
Dortmund	8	currently under GEF's investigation	
Würzburg	18	currently under GEF's investigation	



Conversion in Ulm (South Germany)



Goal of the preliminary study:

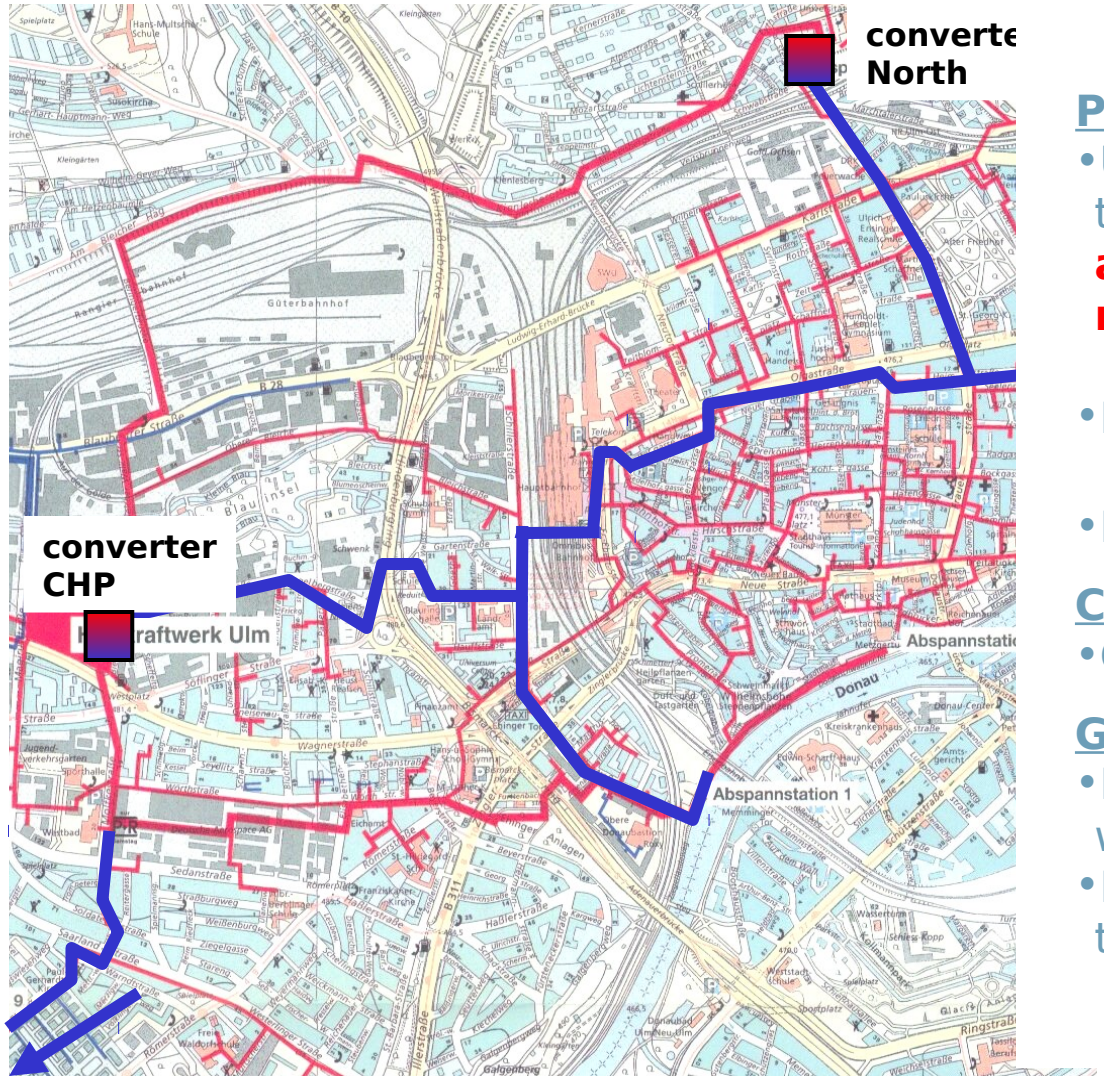
Issuing a concept for the DH in Ulm for the long term. The main focus lies on the technological and economical feasibility of a conversion of the steam into a hot water DH system.

Agenda:

1.) Preliminary study:
In case of positive conclusions regarding technical and economical feasibility of a steam to hot water conversion, the next step follows

2.) Detailed concept:
Issuing a detailed conversion concept with annual steps for Ulm.

Technical Concept



Piping system

- Utilisation of the existing pipes until the end of their technical lifetime; **additional hot water pipes as new backbone**
- Parameters: pressure PN 232
  T_{flow} = 250°F
- Integration of *anyway*-measures

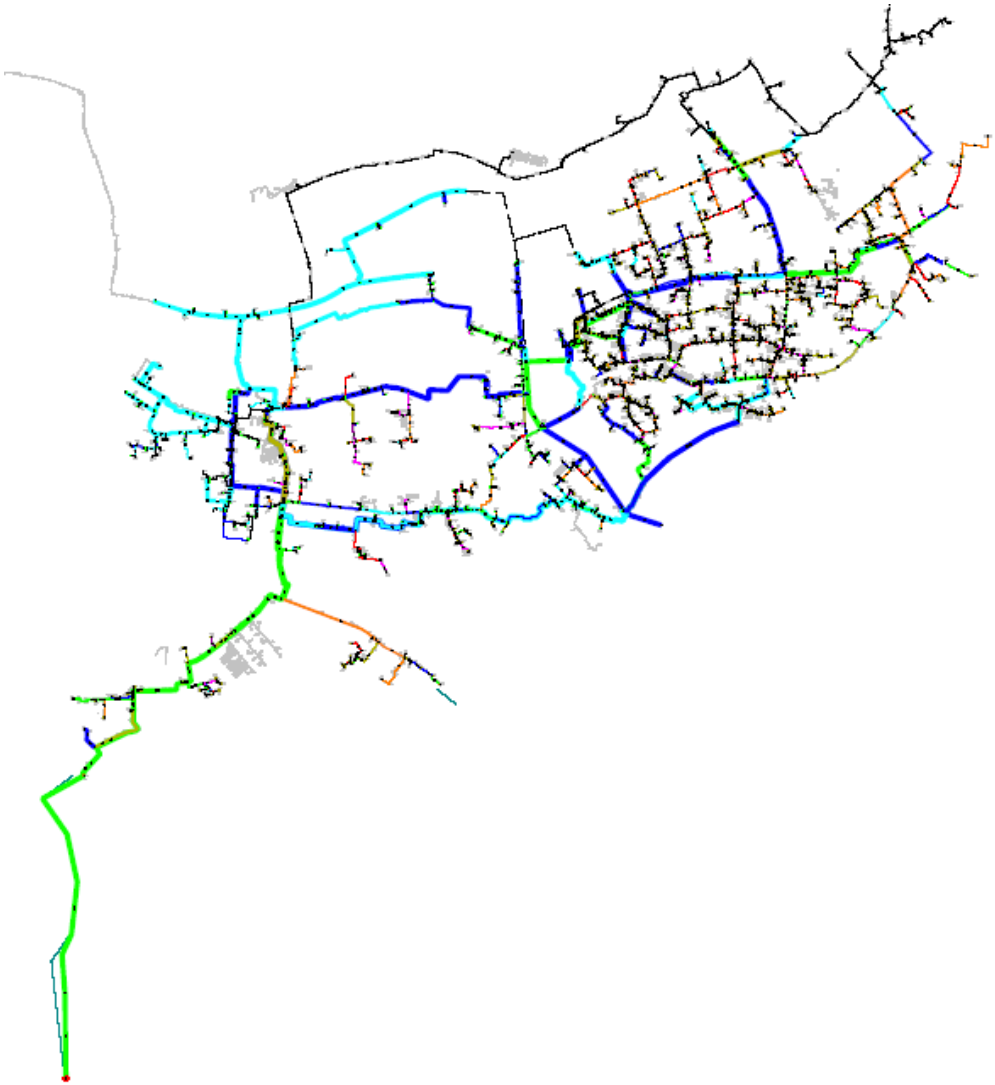
Customers

- Change of all customer installations

Generation

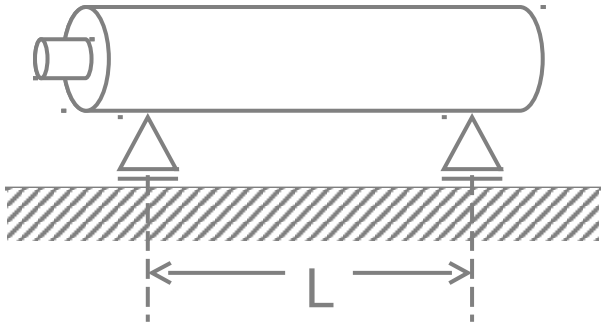
- Installation of new steam to hot water converters CHP and North
- More efficient utilisation of fuel in the energy plants

Hydraulic Feasibility Approved



- Computation of a peak load case:
  P_{max} = 8,140 MMBtu
- Temperatures:
  T_{flow} = 250°F (former: 375°F)
  T_{return} = 140°F (former: 220°F)
- Pressures:
  $p_{flow,\ max}$ = 160 psig
  Δp_{min} = 14.5 psig
- Max. water speed in condensate pipes: 8.2 – 9.8 ft./s
- Pressure losses: **supply** low, **return** high

Static Mechanic Feasibility



steam content water content

DN 25 - 150 | DN 200 - 450

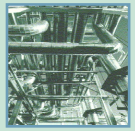
DN Dampf	Da × s	Kond.	a	b	c	d	e	f	g	H	H+c	h	i	k	l	Stützweite m D.	K.
25	33,7 × 2,6	25	650	150	-	300	240	65	455	116	-	116	40	173	65	1,8	2,6
32	42,4 × 2,6	25	650	150	-	300	240	65	455	120	-	116	40	181	60	2,1	2,6
40	48,3 × 2,6	25	850	150	-	450	350	80	580	133	-	116	50	207	120	2,5	2,6
50	60,3 × 2,9	25	850	150	-	450	350	80	580	139	-	116	60	229	105	3,2	2,6
65	76,1 × 2,9	25	850	150	-	450	350	80	580	198	-	116	70	306	85	4,0	2,6
80	88,9 × 3,2	25	850	150	-	450	350	80	580	205	-	116	80	330	70	4,4	2,6
100	114,3 × 3,6	32	850	150	-	450	400	80	630	237	-	120	100	394	40	4,7	3,0
125	139,7 × 4,0	32	950	170	-	600	500	120	790	252	-	120	100	422	100	5,4	3,0
150	168,3 × 4,5	40	950	170	-	600	500	120	790	266	-	133	100	450	85	6,1	3,4
200	219,1 × 5,9	50	1300	200	80	800	700	120	1020	292	372	139	120	602	80	7,7	4,0
250	273 × 6,3	65	1300	200	80	800	700	120	1020	329	409	198	130	676	50	8,5	5,0
300	323,9 × 7,1	80	1300	200	80	800	760	120	1080	354	434	165	140	736	40	9,4	5,3
350	368 × 8,0	2×80	1600	220	115	1100	900	120	1240	376	491	205	160	835	-	10,3	5,3
400	419 × 10	2×80	1600	220	80	1100	900	120	1240	402	482	205	160	852	-	11,3	5,3
450	457,2 × 10	2×80	1600	220	65	1100	900	120	1240	421	486	205	160	875	-	12,3	5,3

Energie-Versorgung Schwaben AG — Kraftwerk Ulm, Einsteinstraße 20

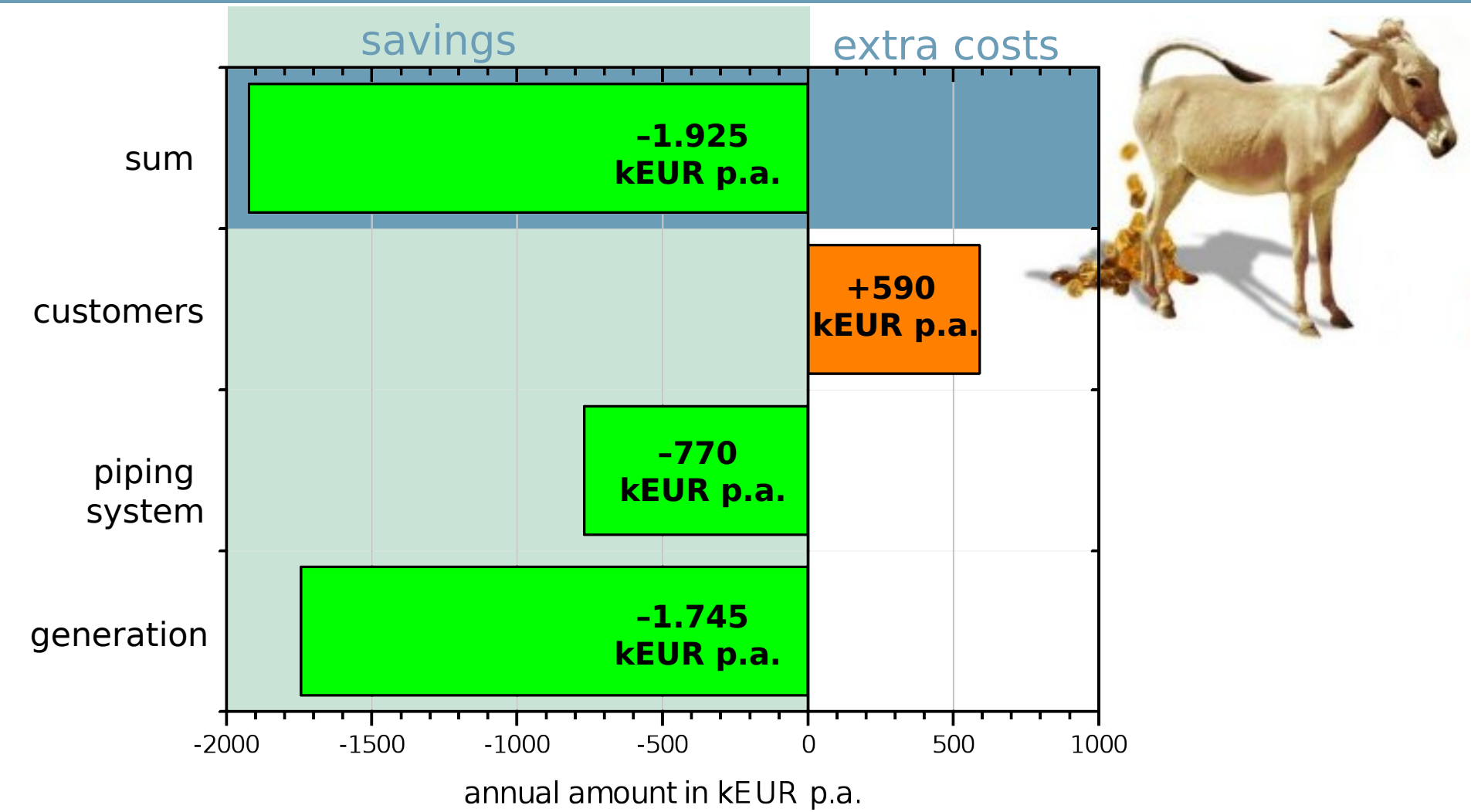
Source: FUG

DN	span [m]
25	4.71
32	5.45
40	5.59
50	6.29
65	6.84
80	7.41
100	8.24
125	9.29
150	10.35
200	12.13
250	13.09
300	14.18
350	15.11
400	16.98
450	17.29

- Width between two supports of steam pipes is sufficient for charging pipes with water
- Wall thickness is sufficient for a pressure grade of PN232 (= 16atm)
- Since numerous of the existing pipes are up to 50 years old and some pipes and trenches are in a bad shape damages as a consequence of water charging must be taken into account.



Cumulated Costs



Conversion is beneficial

The calculated savings and extra costs has been agreed by a working of the FUG, which consists of all departments.

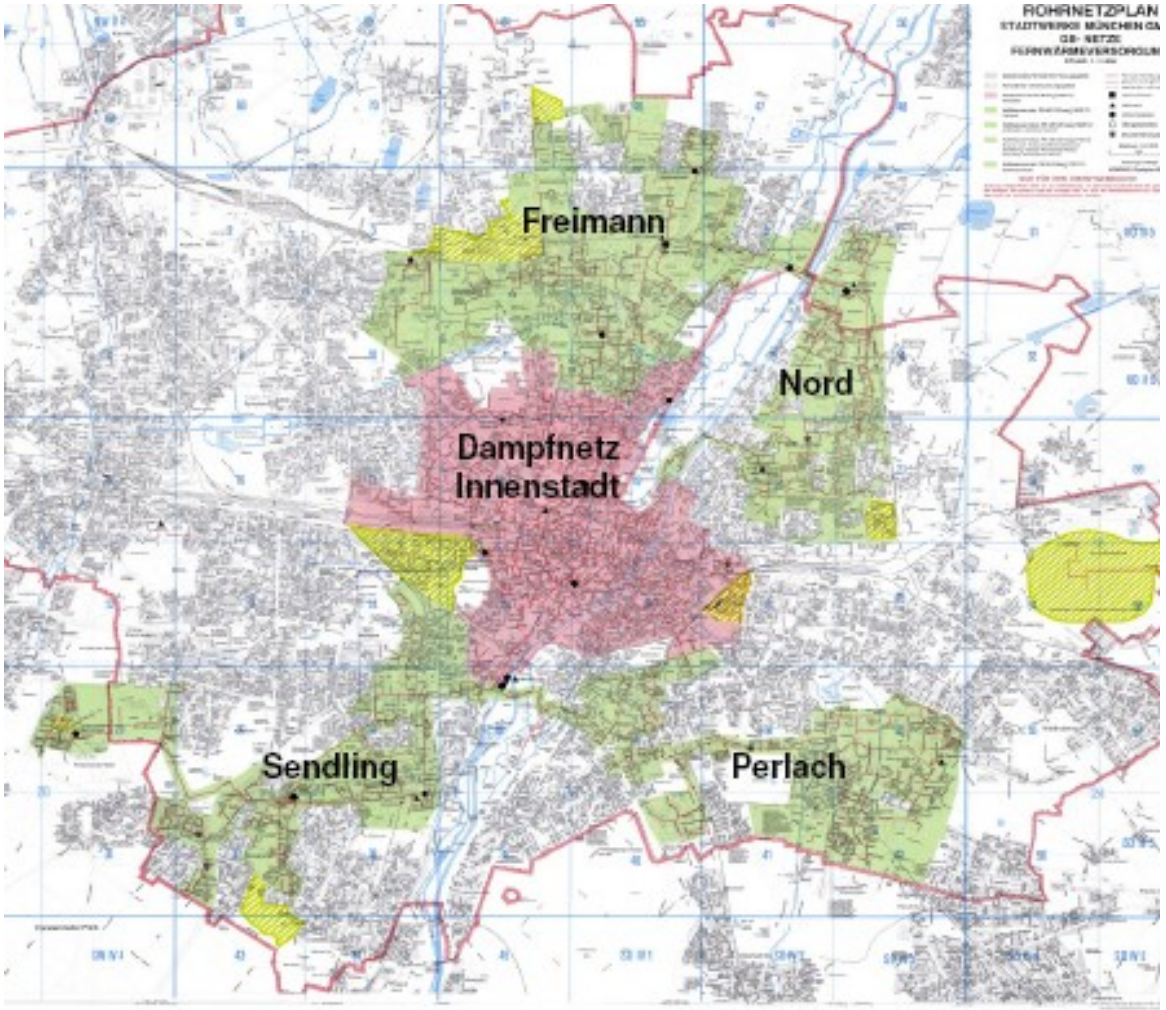
The conclusion is:

- The conversion is technically **feasible**
- The conversion is under static economic calculations **beneficial**
- The conversion is under ecological terms **sustainable**

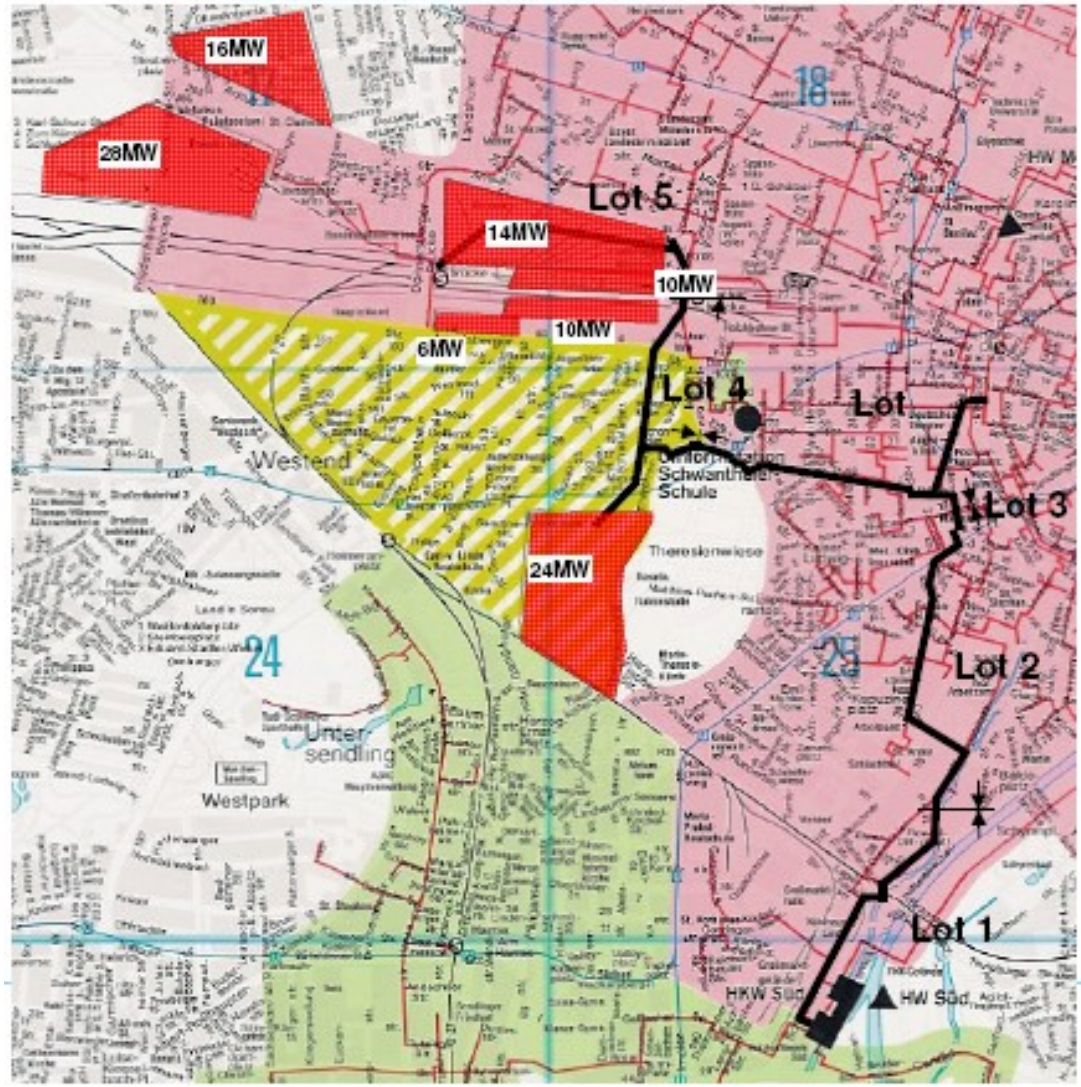
Initial Situation

In Munich Germany's largest steam DH system is operated

- 5 different DH systems in Munich
- The largest DH system is the steam DH system in the city centre
- 150 miles stretch
- 65 Bil. Btu/h connected load
- 4,400 customer installations



Why doing a Conversion

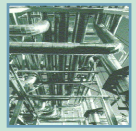


Since there are numerous problems in a steam based DH system, its sustaina-bility is doubtful. Possible alternatives are:

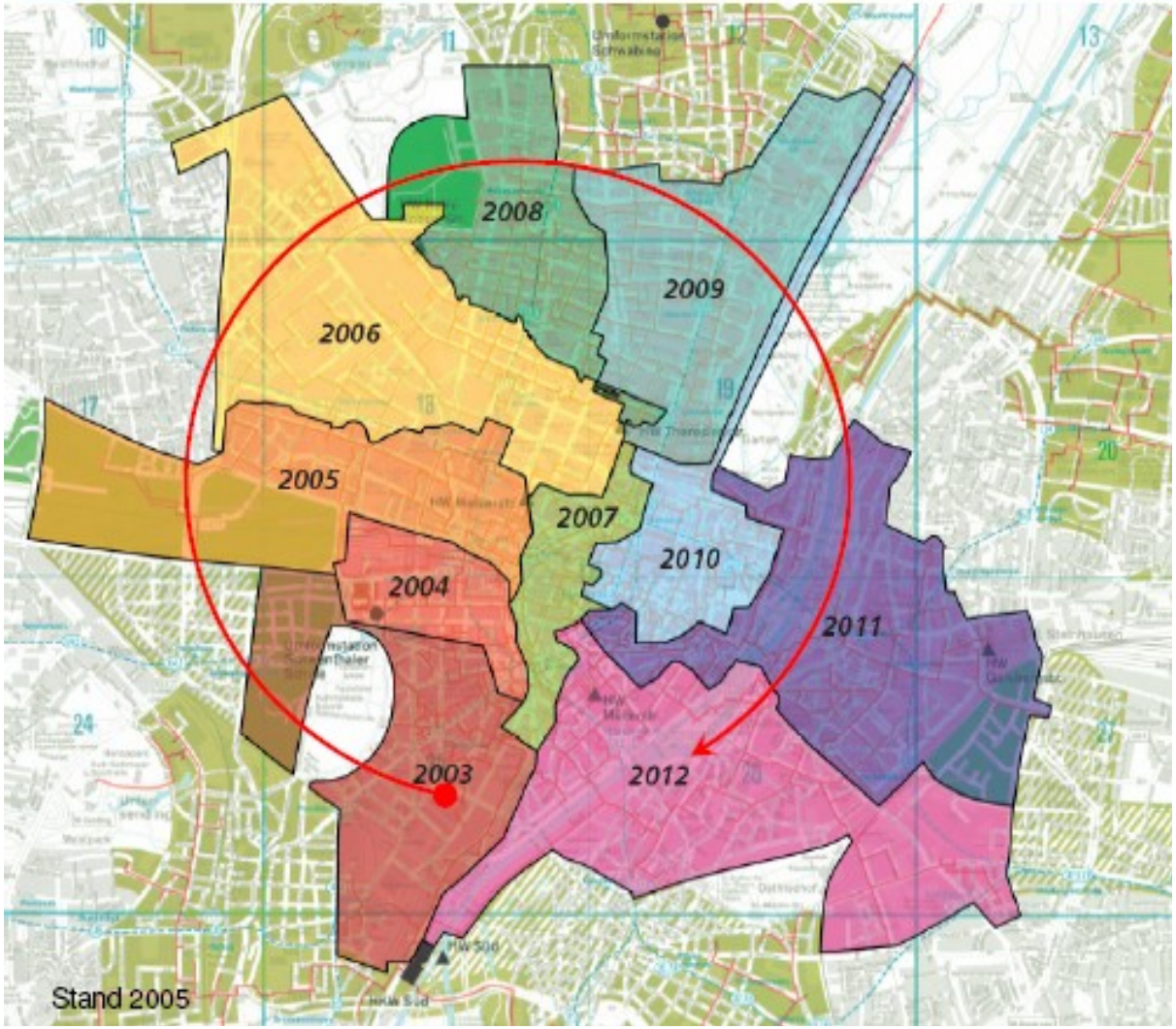
- Optimisation of the steam DH system
- Stepwise replacement of DH by natural gas
- Stepwise replacement of steam by hot Water DH systems

Specific Problems of steam DH:

- numerous pit holes
- high heat losses
- difficult controlling, steam shocks
- intricate condensate operation
- costly O&M
- costly renovation
- the existing steam system cannot meet the estimated heat demand in the western city



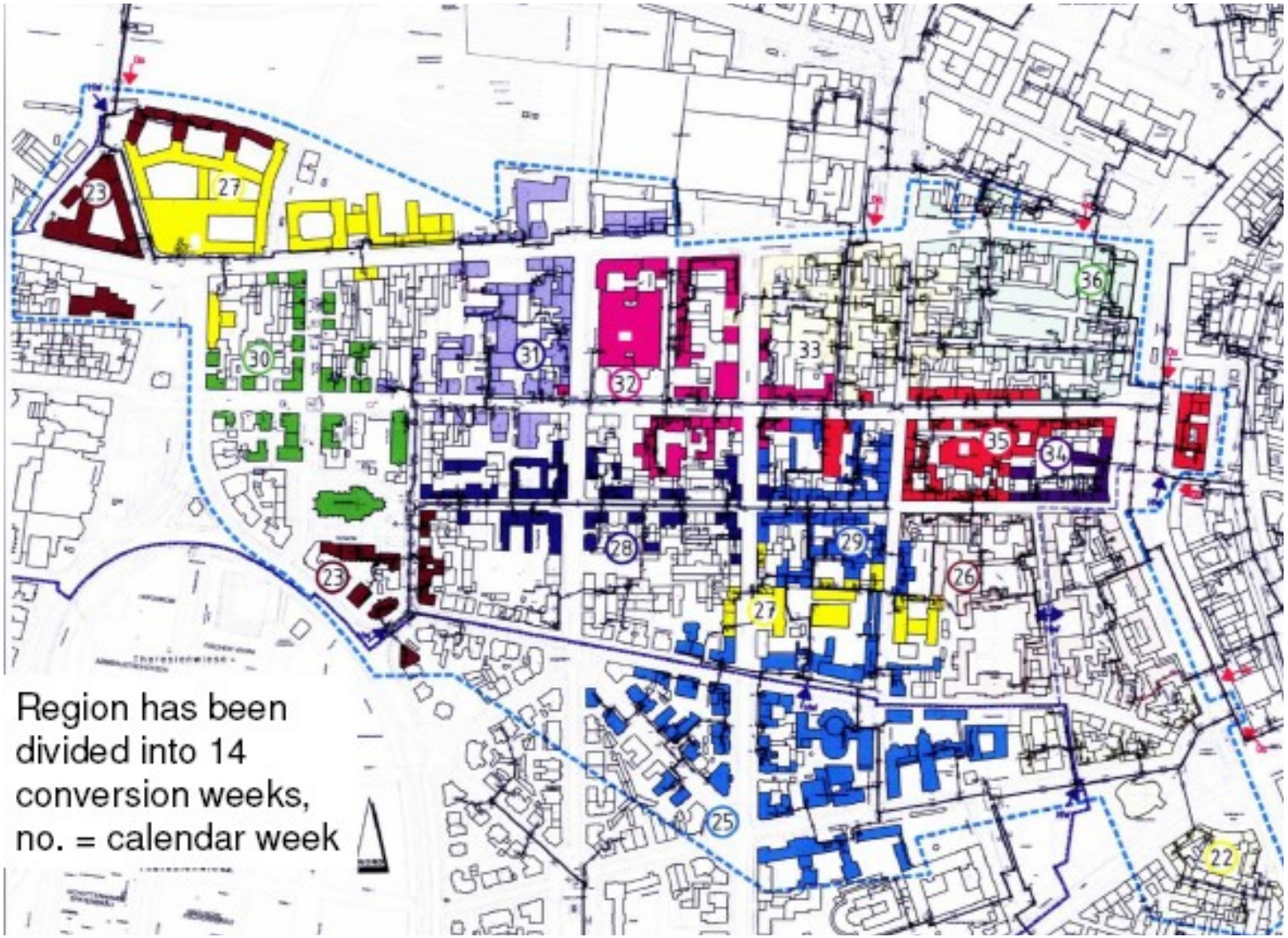
Decided Proceeding



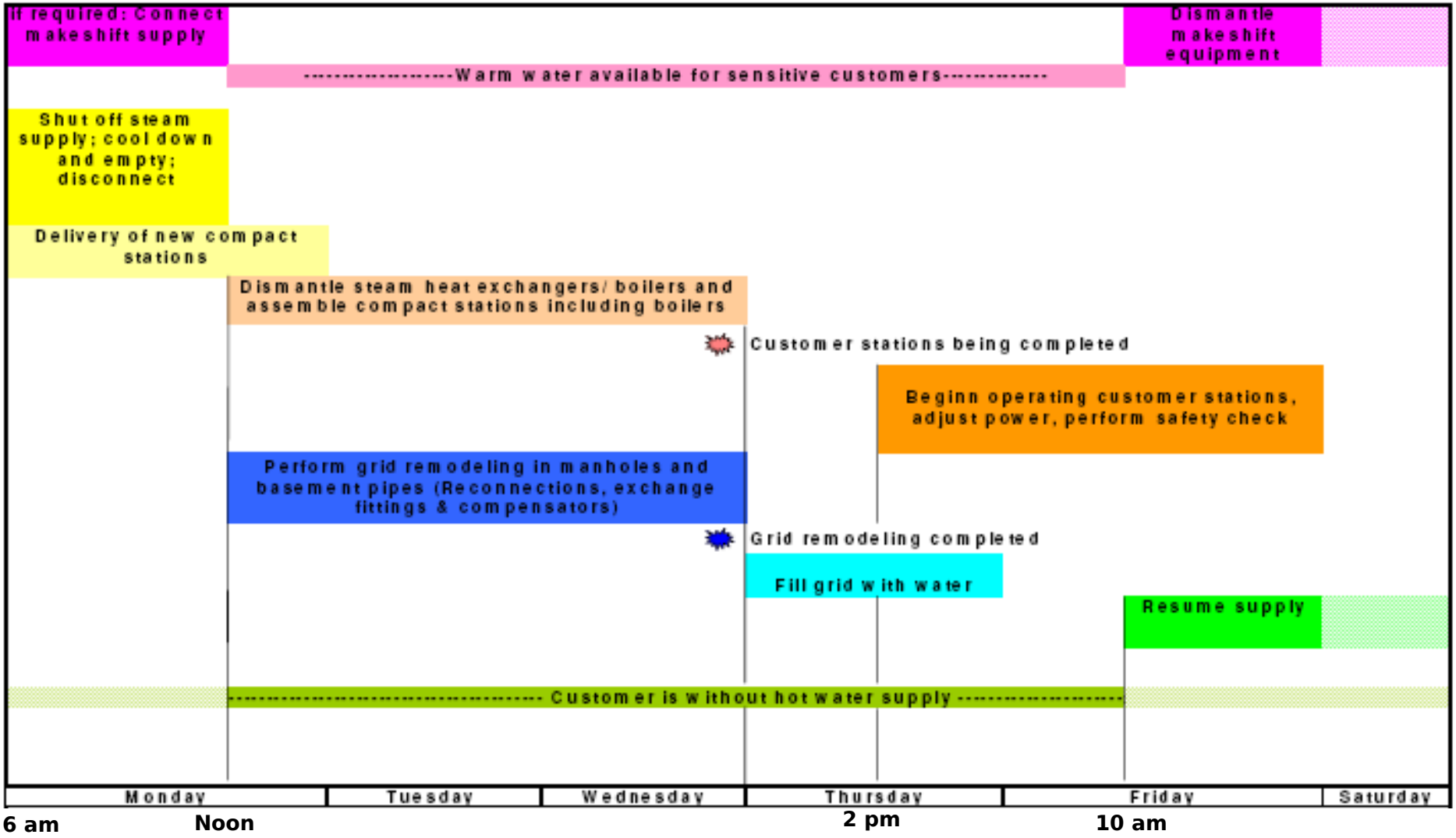
The conversion started with the first of ten annual steps in 2003. Origin is the area next to the CHP-plant in the south (HKW Süd). The further steps are going clockwise.

The figure shows the status of September 2001.

Weekly Approach in an Annual Step (2004)

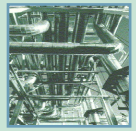


Schedule of one Week during Conversion: Extreme busy and


If required: Connect makeshift supply
Dismantle makeshift equipment
Warm water available for sensitive customers
Shut off steam supply; cool down and empty; disconnect
Delivery of new compact stations
Dismantle steam heat exchangers/ boilers and assemble compact stations including boilers
Customer stations being completed
Beginn operating customer stations, adjust power, perform safety check
Perform grid remodeling in manholes and basement pipes (Reconnections, exchange fittings & compensators)
Grid remodeling completed
Fill grid with water
Resume supply
Customer is without hot water supply
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
6 am
Noon
2 pm
10 am

Conclusion from Munich: Steam to Hot Water DH conversion with using the existing Piping

- Experiences from 3 years of conversion with about 1,000 customers approved the concept developed by GEF and SWM
- Customers' acceptance is given and ensured through attending measures and PR-work
- Organisational structure of the conversion processes is approved and under further optimisation
- Exemplary investment program (more than 110 Million EUR) supports medium-sized businesses in many parts of Germany



Lessons learnt from the Examples

- Starting in Munich the **trend to reduce the DH supply temperature** in Europe is obvious. We suppose the conversion of all steam DH systems in a couple of years (maybe within the next two decades).
- **Economic reasons** are the minimised heat losses, the reduced O&M efforts, the cost reductions in piping, the high efficient operation of CHP-plants, the integration of waste heat source and numerous more.
- However, obtaining an economical conversion requires the reduction of expenses into the piping system. Thus, the **extended utilization of the existing pipes** is essential.
- To achieve the conversion under technical and economical conditions, the installation of a **new hot water backbone** was found **helpful**.
- Finally, the end of the of trend to reduce the supply temperatures currently is not conceivable. A soft technical limitation is through the avoidance of the legionnaires' disease

Questions? Contact?

Further Information on the Web:

http://www.gef-ingenieur-ag.de/

Service Spectrum of GEF Ingenieur AG

GEF is a Full-Liner for Engineering Services for pipeline-bound Energy supply

- Preparation of the Decision-Making Process
- Special Calculations with self-developed Software
- Planning Processes
- Special Services and Care until Commissioning
- Training courses for our Software

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